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SciVerse ScienceDirect
Procedia Engineering 45 (2012) 225 – 230
Procedia Engineering
www.elsevier.com/locate/procedia

2012 International Symposium on Safety Science and Technology

Establishment and application of intrinsic coal-workman evaluation model based on wavelet neural network

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Abstract

Mine is a complex and changeable workman-machine-environment-management system. Using the workman-machine -environment-management system theory and taking the coal workman as the research object, discussed the cause of workman error and the accident mode caused by workman error on the basis of workman behavior theoretic analysis. Studied the identification technique and control method of workman error, and established intrinsic workman evaluation index system, and then used fuzzy theory to construct membership functions for influencing factors, finally made simulation analysis of intrinsic coal-workman using the data from HuangLing No1 mine in ShannXi by wavelet neural network, and proposed some corresponding approaches and methods for realizing intrinsic safety. This study can provide some decision supports to mine, it also have a great help to reduce workman unsafe behavior, avoid the occurrence of accidents, and achieve mine's sustainable development.

Keywords: coal workman; intrinsic safety; wavelet neural network; evaluating model

1. Introduction

Workman is the main part of the safety production, the workman qualities, such as physiological status, safety psychology, technology quality and working safety condition, which directly affect the safety production going smoothly. The efficiency development of the each unit in the workface in a great number depends on the operation, maintenance and the management level of workman. In some lager disasters, the number of casualty accidents caused by workman error is amount to 70%-80%, and the behavior uncertainty is the most variable in safety production [1]. The core of the intrinsic safety mine is to realize the workman intrinsic safety [2]. At present, the low quality of the workman is a common problem[3], and the workman system consists of four parts: basic-level, general managers, inspectors and leaders. The first line mining workers fall into three parts: some formal contract workers form technical school, some former who have an agreement and migrant workers based outsourcing project team, the quality of later two types is not higher, most of whom often receive junior education or below, and the safety training is not fulfilled. As the effect of traditional concepts and behaviors, the workman often are limited by the outdate concept, can not receive new concepts, the awareness and the responsibility severely, and treat the current development and the safety production situation correctly. The different levels of workman's quality and the shortage of technical are the most difficult problem of prevention and control in intrinsically safe coal mine construction.

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doi:10.1016/j.proeng.2012.08.148

2. Cause Analysis of Workman Unsafe Behavior

All of the machines, equipments and tools in the mine are operated by workman. To achieve the production, workman must work in the special environment, so the workman must be connected strongly with all the devices to form an integral, which is the workman-machine-environment system. In the system, the three factors interact and mutually restrict with each other, and the workman is the main one [4-5]. In all the systems, as any accident can be rooted in the workman, the main object of safety management is workman. And the unsafe behavior and mechanical or environment hazards are some energy reverse-flow types, the crossing point of them can result in the accident. Above all the key of the unsafe behavior is to analyze the possibility of workman error [6], which relates to the internal and external elements, the influencing factors as follows:

•Physiological status, it includes three elements: healthy condition, labor intensity and workload. Healthy condition, the occurrence of the accident is relative to the healthy condition, the workman with physical defects and bad habits easily has a tendency to accident; Labor intensity, the increase of the labor intensity, for the workman, implies that the work density is bigger, that will leads to the amount of the work increase, what is worse, the mental nervousness will present; Work load, that means the amount work workman can undertake per hour, and includes physical and psychological load. As we all know, the rational workload directly affects the work efficiency, which embodies on the quality and quantity.

•Psychological state, when the workman is being unstable states, something may go wrong, the psychological elements (tension, fatigue, mental disorder) contain emotional features, work satisfaction and work pressure.

•Safety education, it includes three elements: the level of education, safety attitude and work matching degree.

•Technical situation, it contains the accuracy of operation, the work experience and fuzzy safety state.

3. Establishment of workman intrinsic safety evaluation index system

According to the analysis above, the intrinsic workman evaluation index system was established as Table 1.

Table 1. The workman evaluation index system

The intrinsic workman safety A	
Second level index	Third level index
Physical state B_1	Healthy state C_{11}
	Labor intensity C_{12}
	Workload C_{13}
Psychological state B_2	Emotion C_{21}
	Satisfaction C_{22}
	Work press C_{23}
Safety education B_3	Education level C_{31}
	Safety attitude C_{32}
	Work matching C_{33}
Technical condition B_4	Accuracy operation C_{41}
	Fuzzy safety C_{42}
	Simulation values C_{43}

Physiological status. Its membership function as follows:

$$u(x_1) = \begin{cases} 1 & x_1 \le 0.02 \\ (0.1 - x_1)/0.08 & 0.02 < x_1 \le 0.1 \\ 0 & x_1 > 0.1 \end{cases} \quad . \tag{1}$$

Labor intensity. Its membership function as follows:

$$u(x_2)=\begin{cases}1 & x_2\le 0.2\\ (0.5-x_2)/0.3 & 0.2<x_2\le 0.5\\ 0 & x_2>0.5\end{cases} \quad (2)$$

Work load. The membership function given by the modified Cooper-Harper quantitative table.

Psychological feature, its membership function as follows:

$$u(x_4)=\begin{cases}1 & x_4\le 20\\ (50-x_4)/30 & 20<x_4\le 50\\ 0 & x_4\ge 50\end{cases} \quad (3)$$

Work satisfaction. With the form of direct inquiry, the membership function given by the ratio of work satisfaction as follows:

$$\mu(x_5)=\begin{cases}0 & x_5\le 0.8\\ 10(x_5-0.8) & 0.8<x_5\le 0.9\\ 1 & x_5>0.9\end{cases} \quad (4)$$

Work pressure. It consists of four parts: the importance, arduousness, urgency and the risk, the membership function given as follows:

$$\mu(x_6)=(\mu(x_{61})+\mu(x_{62})+\mu(x_{63})+\mu(x_{64}))/4 \quad (5)$$

Education degree. The education degree can be determined by the ratio the junior graduates, the membership function given as follows:

$$\mu(x_7)=\begin{cases}0 & x_7\le 0.5\\ (0.8-x_7)/0.3 & 0.5<x_7\le 0.8\\ 1 & x_7>0.8\end{cases} \quad (6)$$

Safety attitude. It rests on the attitude of the workman, the membership function given as follows:

$$\mu(x_8)=\begin{cases}0 & x_8\le 0.80\\ 10(x_8-0.8) & 0.8<x_8\le 0.90\\ 1 & x_8>0.9\end{cases} \quad (7)$$

Work match. It can be determined by the workman's approve of the safety goal, the membership function given as follows:

$$\mu(x_9)=\begin{cases}0 & x_9\le 0.80\\ 10(x_9-0.8) & 0.8<x_9\le 0.90\\ 1 & x_9>0.9\end{cases} \quad (8)$$

Accuracy of operation. Its membership function given as follows:

$$\mu(x_{10}) = \begin{cases} 0 & x_{10} \le 0.85 \\ 10(x_{10} - 0.85) & 0.85 < x_{10} \le 0.95 \\ 1 & x_{10} > 0.95 \end{cases} \tag{9}$$

Work experience. It can be determined by ratio of workman with three years or more experience, the membership given as follows:

$$\mu(x_{11}) = \begin{cases} 0 & x_{11} \le 0.85 \\ 10(x_{11} - 0.85) & 0.85 < x_{11} \le 0.95 \\ 1 & x_{11} > 0.95 \end{cases} \tag{10}$$

Fuzzy safety state. Its membership function as follows [7]:

$$\mu(x_{12}) = \begin{cases} 0 & 0 \le x_{12} \le 0.6 \\ 2(\frac{x_{12} - 0.6}{0.4})^2 & 0.6 < x_{12} \le 0.8 \\ 1 - 2(\frac{x_{12} - 1}{0.4})^2 & 0.8 < x_{12} \le 0.83 \\ 1 - [1 - 2(\frac{x_{12} - 1}{0.4})^2]^2 & 0.83 < x_{12} \le 1 \end{cases} \tag{11}$$

4. Wavelet neural networks evaluation model

4.1. Wavelet neural networks

WNN is the combination of wavelet theory and Neural Networks, the fusion of wavelet decomposition and feed forward neural network. The typical network model with three layers of WNN is shown as Fig 1. It is assumed to have N samples. $x_j^k = \{x_j^k\}$, (k=1, 2, …, N) (j=1, 2, …, m, m is the number of input nodes), and the corresponding object output is D^k. in the network there are M input nodes, only one output node; W_i means the weights of wavelet unit i, (i=1, 2, …, n, n is the amount of intermediate layers); U_{ij} is the weights connected the input j-th input x_j to the wavelet unit i, and the wavelet network output as follows:

$$y^k = \sum_{i=1}^{n} W_i \psi \left[\frac{\sum_{j=1}^{m} U_{ij} x_j^k - b_i}{a_i} \right] \tag{12}$$

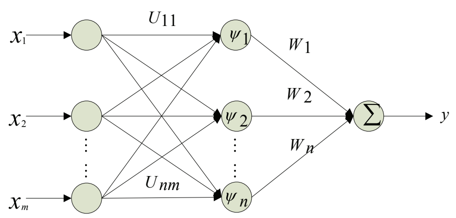

Fig. 1. The WNN structure.

As for the input and output ($\{x_j^k\}, D^k$), the values of network parameters (U_{ij}, a_i, b_i W_i) can be determined by study and training. With the energy error function, the values can be optimized, the sum of error as follows:

$$E = \frac{1}{2N} \sum_{k=2}^{N} (y^k - D^k)^2 \tag{13}$$

4.2. Training process and procedure of WNN

With the Propagation Algorithm, the wavelet parameters and the network connection weight can be adjusted, the Algorithm as follows:

① Initialization. Initialize the values of dilation factor a_i, displacement factor b_i, and the network connection weights U_{ij}, W_i with a random initial value nearby zero.

② Input the learning samples $\{x_j^k\}$, ($j = 1,2,..., m$, $k = 1,2,..., N$); the object output D^k, N is the amount of the samples, m is amount of nodes.

③ Learning course of WNN. Compute the output values of the model.

④ With the use of steepest descent method, to modify the network parameters.

⑤ End the course when the error is less than the presumed value or the steps are more than the max training step, otherwise return ②.

5. Example study

Huangling mining group No1 mine was put into production in Nov, 2001, after five years' technology improvement and equipment upgrades, the mechanical level rise to 100%. At present, the ability of production has reached to 6 billion ton per year. According the evaluation index system, collected the data from the mine in a year, used {0.9-1, 0.8-0.9, 0.7-0.8, 0.6-0.7, 0-0.6} to represent intrinsic mine level {I, II, III, IV, not reached} and normalized data in Table 2, make the former 10 column data which represent 10 months safety assessment data with corresponding to the actual safety evaluation value as the target output as evaluation of training samples to train the WNN model, the later two months sample represent 2 months the safety assessment data. The training results of WNN for workman intrinsic safety evaluation shown as Fig. 2, the evaluation output value of WNN for the last two month evaluation samples are (0.85, 0.89).

Table 2. The values of evaluation indexes

No Indexes	1	2	3	4	5	6	7	8	9	10	11	12
Healthy state	0.9	0.85	0.91	0.95	0.85	0.86	0.83	0.74	0.88	0.83	0.91	0.85
Labor intensity	0.85	0.97	0.99	0.75	0.88	0.88	0.96	0.73	0.8	0.76	0.77	0.79
Workload	0.82	0.82	0.71	0.86	0.95	0.66	0.83	0.83	0.73	0.76	0.96	0.67
Emotion	0.86	0.72	0.8	0.71	0.7	0.85	0.84	0.92	0.92	0.77	0.85	0.79
Satisfaction	0.92	0.9	0.99	0.85	0.88	0.74	0.93	0.89	0.98	0.85	0.78	0.82
Work press	0.86	0.96	0.75	0.96	0.86	0.85	0.97	0.94	0.75	0.87	0.75	0.95
Education level	0.46	0.47	0.37	0.48	0.4	0.4	0.45	0.53	0.5	0.54	0.72	0.73
Safety attitude	0.65	0.75	0.59	0.66	0.75	0.52	0.62	0.67	0.54	0.63	0.8	0.77
Work matching	0.73	0.6	0.81	0.72	0.8	0.88	0.77	0.79	0.72	0.62	0.8	0.82
Accuracy operation	0.85	0.73	0.83	0.82	0.72	0.86	0.82	0.97	0.86	0.85	0.85	0.9
Work experience	0.58	0.59	0.66	0.65	0.68	0.68	0.61	0.55	0.61	0.53	0.86	0.83
Fuzzy safety	0.98	0.95	0.9	0.8	0.97	0.86	0.89	0.89	0.93	0.97	0.95	0.97
Expected output	0.9	0.85	0.83	0.83	0.84	0.85	0.85	0.83	0.86	0.9	-	-
WNN simulation values	-	-	-	-	-	-	-	-	-	-	0.85	0.89

According to evaluation results above, the intrinsic safety workman management level of this mine is being improving continuously, but there are still some problems in workman safety training, safety education and so on, so come to the following recommended measures:

Intensify training and improve the standardizing consciousness and operational skills, intensify education and learn, at same time, establish the workmen safety consciousness and make a foundation for promoting intrinsic safety, strengthen the business training, and improve the quality of the team, standard the workmen operation behavior.

Build "four No" group. It refers to "no hidden trouble, no operational behavior, no accident about quality, no production pollution". The mine must combine its own reality to identify education training and management, which can be bound to keep production safety.

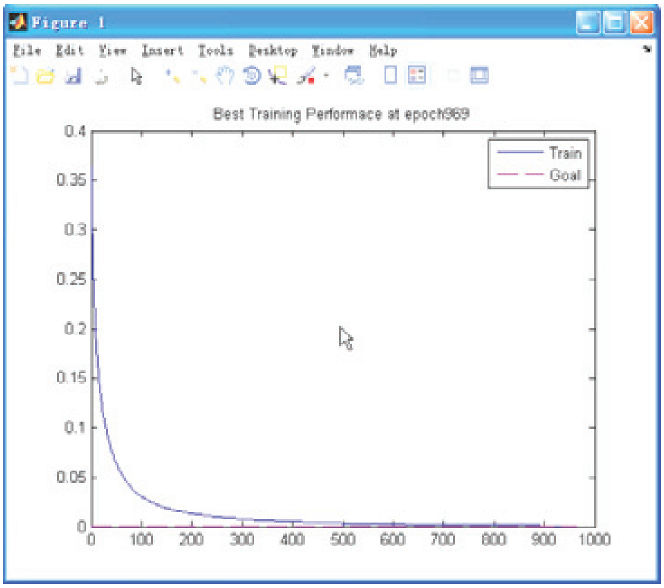

Fig. 2. The training of WNN for workman intrinsic safety evaluation.

Promote the “mouth-hand” operation style greatly, that means workman should keep the habit of the safe behavior, with eye-watching, heart-minding, mouth-speaking and hands-pointing.

According to the data analysis, the workman structure has some unreasonable problems, the percentage of the workman blow senior education degree are very common, so during the course of promoting the mine construction, the shortage of talents is a hidden danger, it needs to the introduction of talents and strengthen the training.

6. Conclusion

As the system of man being thoroughly studied, an overall Evaluation about Man of intrinsic safety in coal mines is put forward. Through the evaluation model verification, thus provides an important assistance in decision making. The concept of Intrinsic Safety in coal mines safety management is a new ideology, which will greatly promote the improvement of safety management and safety control standard in coal mines to build a safer and more productive industry.

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